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TITLE OF THE INVENTION

COLOR CORRECTION TABLE COMPILING METHOD, CONTROLLING PROGRAM,
RECORDING MEDIUM, AND DEVICE

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BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a color
10 correction table compiling method, a control program, a
recording medium, and a device.

Description of the Related Art

[0002] In general, image color can vary between images
displayed on a color monitor and the same images when
15 printed on a printer. This may be due to gamut differences
or color reproduction differences between the monitor and
the printer. Accordingly, there is the need to perform
color matching to adjust color so that the way the monitor
displays color and the printed color match. As an example
20 of color matching processing, an interpolated color
correction lookup table (hereafter, "color correction
table") based upon color properties of the monitor and the
printer can be employed.

[0003] However, the color correction table can contain
25 errors due to various types of noise such as measurement

and/or quantization errors. Such noise can cause the smoothness of the conversion curve obtained from the color correction table to become deteriorated. As a result, artifacts or the like are present when the image is printed.

5 [0004] Conventional systems for smoothing color correction table values in order to remove noise are known. In Japanese Patent Laid-Open No. 2001-308643, for example, values of the color correction table corresponding to achromatic color ($R = G = B$) are kept the same in order to 10 keep achromatic data values of the input image achromatic during color conversion.

15 [0005] However, when the color correction table values corresponding to achromatic color are used without change as in the above-described conventional method, achromatic colors are not subjected to smoothing. In some cases, this can result in artifacts due to deterioration of the smoothness of the tone sequence, and in particular, on a gradation image with complementary colors containing 20 achromatic color in between.

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SUMMARY OF THE INVENTION

[0006] The present invention has been made to solve the above problems, and accordingly it is an object thereof to 25 provide a method wherein smoothing is performed for color

values corresponding to achromatic color. The smoothing process uses colors surrounding the color values, and also maintains the achromatic nature of the color values. This process causes artifacts and noise occurring around 5 achromatic color to be suppressed, thereby improving image quality.

[0007] As means for achieving the above-described object, a color correction table compiling method of the present invention includes a configuration described below.

10 [0008] A color correction table compiling method according to the present invention, comprises: receiving color values of a color space stored in the color correction table; smoothing the color values to provide first color values corresponding to achromatic color in the color space; 15 in the event that the first color values does not correspond to achromatic color due to the smoothing, adjusting the first color values to provide second color values corresponding to the achromatic color in the color space; and storing the second values in the color correction table.

20 [0009] Adjusting may be performed so that the second value is converted to a value on the achromatic axis, or may be performed so that the second value is projected onto the achromatic axis in the color space. The method may further comprise defining selected conditions for performing the 25 smoothing, and the smoothing conditions may comprise limit

values as to the amount of change between the color values before and after smoothing, and further, the smoothing conditions may be each set for achromatic color and other colors. Also, the smoothing conditions for achromatic color 5 may be based upon limit values as to the amount of change in color at a plurality of positions on the achromatic axis.

[0010] Furthermore, the method may further comprise providing a control program and a computer for executing the method for compiling a color correction table.

10 [0011] Furthermore, the method may further comprise providing a storage medium for storing the control program.

[0012] Furthermore, a device for compiling a color correction table having color values in a color space, comprises: a smoothing unit for performing smoothing for 15 values in achromatic color in the color space; and a correction unit for adjusting the first values into second values corresponding to achromatic color, in the event that the first values do not corresponds to achromatic color due to the smoothing.

20 [0013] Further objects, features and advantages of the present invention will become apparent from the following description of the preferred embodiments (with reference to the attached drawings).

[0014] Fig. 1 is a block diagram, which illustrates a configuration of an image processing device to which a color adjustment device according to a first embodiment of the present invention is applied.

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[0015] Fig. 2 is a schematic diagram, which illustrates a layout of grid points before color correction processing in the RGB space.

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[0016] Fig. 3 is a diagram which shows data rows held by a color correction table.

[0017] Fig. 4 is a schematic diagram, which illustrates a layout of grid points after color correction processing in the RGB space.

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[0018] Fig. 5 is a flowchart, which shows smoothing process.

[0019] Fig. 6 is a diagram for describing processing for adjusting a gray value deviating from the achromatic axis to return the value to the achromatic axis.

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[0020] Fig. 7 is a block diagram, which illustrates a configuration of a color adjustment device according to a second embodiment of the present invention.

[0021] Fig. 8 is a diagram, which illustrates an example of a display screen for setting limit values as to the amount of change due to smoothing.

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[0022] Fig. 9 is a flowchart, which shows smoothing

process according to the second embodiment of the present invention.

[0023] Fig. 10 is a diagram, which shows the relation between color values before smoothing, after temporary smoothing, and after smoothing.

[0024] Fig. 11 is a diagram, which illustrates an example of a display screen for setting limit values as to the amount of change due to smoothing.

[0025] Fig. 12 is a block diagram, which illustrates a configuration of a computer according to another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 First Embodiment

[0026] Fig. 1 is a block diagram, which illustrates a configuration of an image processing device according to a first embodiment of the present invention. As shown in Fig. 1, a color monitor 10 for displaying an image and a printer 17 for printing the image on a recording medium are connected to an image processing device 18. The image processing device 18 includes a video signal generating unit 11 for converting image data into video signals.

[0027] Image memory 12 stores temporarily image data and 25 permanently stores the image data in a storage device 19

such as a hard disk or the like. A color correction table 13 stores the relation between printed color and color displayed on a monitor. A color matching processing unit 14 performs color matching between the displayed color and the 5 printed color. A smoothing unit 15 performs the smoothing process for data stored in the color correction table 13. An output image processing unit 16 converts the image data into signals for driving printers.

[0028] The image data to be processes may include data 10 digitized by an image input device such as a digital camera, scanner, computer graphics (CG) generated data and the like. Further the image data is stored in the image memory 12 as pixel values corresponding to luminance. Each pixel value 15 is an 8 bit value representing red (R), green (G), and blue (B).

[0029] In Fig. 1, the color monitor 10 is a display device such as a CRT, an LCD, or the like. The printer 17 uses ink jet technology that affixes printing inks cyan (C), magenta (M), yellow (Y), and black (K) to a substrate such 20 as paper. Note that other types of color monitors and printers using other methods such as electrophotographic printers, thermal transfer printers, or the like, may be employed by the present invention.

[0030] The color correlation table 13 is used for color 25 correction processing for the input RGB values based upon

the output properties of the printer 17, and accordingly stores the relation between color coordinates of regular spaced grids in the RGB color space and the color coordinates subjected to color correction processing.

5 [0031] Fig. 2 is a schematic diagram, which illustrates the grid points in RGB color space before color correction processing is employed. Fig. 2 shows R-axis, G-axis, and B-axis, each having seven grid points. Each grid point, e.g., Grid(6, 0, 6) is a coordinate representable by a R value, a G value, and B value that can represent the primary additive and subtractive colors namely magenta, e.g., M(255, 0, 255), black (Bk), green (G), red (R), cyan (C), and white (W).
10 Fig. 3 shows the color correction table 13 in detail. As shown, the color correction table stores step values for each of R-values, G-values, and B-values, and further stores RGB values obtained after color correction.
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20 [0032] Fig. 4 is a schematic diagram, which illustrates grid points after color correction processing using the color correction table 13. Fig. 4 shows the RGB values after color correction and the grid number of the grid coordinates, corresponding to the representative points of black (Bk), green (G), red (R), cyan (C), magenta (M), and white (W).
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[0033] Referring to the image processing device shown in Fig. 1, the image data input from the storage device 19 and

stored in the image memory 12 is input to the color matching processing unit 14. The color matching processing unit 14 performs color matching for the image displayed on the color monitor 10 via the video signal generating unit 11, and the 5 output image printed by the printer 17 via the output image processing unit 16. Specifically, the output value corresponding to each pixel value of the image data is obtained by performing interpolation with reference to the color correction table 13. Subsequently, the output image 10 processing unit 16 controls the ink emission for each ink of C, M, Y, and K, according to the input RGB pixel value, whereby desirable color is manifested on a recording medium by the printer 17.

[0034] Processing performed by the smoothing unit 15 will 15 now be described with reference to a flowchart shown in Fig. 5. In Step S100, the smoothing unit 15 reads out the RGB values stored in the color correction table 13. Next, in Step S101, the smoothing unit 15 performs smoothing for the RGB values read out by the smoothing unit 15. The smoothing process may be performed by using Gaussian filtering or by 20 averaging adjacent RGB values for each of the R, G, and B color axes. Subsequently, in Step S102, it is determined whether RGB value obtained after smoothing corresponds to achromatic color, i.e., with the RGB value, the relation

holds. If this RGB value is achromatic, the flow proceeds to Step S103. Further in Step 103, if the RGB value deviates from the achromatic axis, it is adjusted so that the RGB value is returned to a value on the achromatic axis.

5 [0035] Fig. 6 is a diagram for describing the aforementioned Step S103, wherein reference numeral 601 denotes the achromatic axis, reference numeral 602 denotes a point deviating from the achromatic axis 601 due to the smoothing process in Step S101, and reference numeral 603 denotes a point after adjustment. With the RGB value at the point 602 deviating from the achromatic axis 601 represented as (r, g, b) , and with the RGB value at the point 603 after adjustment represented as (r', g', b') , the RGB value (r', g', b') is obtained from the expression

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$$r' = g' = b' = (r + g + b)/3.$$

15 [0036] Referring again to Fig. 5, in Step S104, the RGB value after smoothing (and adjustment) is stored in the color correction table 13. Subsequently, the flow proceeds to Step S105, wherein if processing has ended for all the components of the color correction table 13, the processing by the smoothing unit 15 ends. Conversely, if processing has not ended for all the components of the color correction table 13, the processing in Steps S100 through S104 is repeated for the following RGB value.

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25 [0037] With the above-described method, the RGB value

corresponding to achromatic color is subjected to smoothing with reference to surrounding colors while keeping the RGB value after smoothing in achromatic color. Thus, artifacts due to color matching processing can be reduced on a gradation image containing color components on the gray axis.

Second Embodiment

[0038] With a second embodiment of the present invention, in addition to functions of the above-described first embodiment, the user can set limit values for the amount of change in the RGB value from smoothing. Note that the image processing device according to the second embodiment has the same configuration as with the above-described image processing device 18 according to the first embodiment.

[0039] Fig. 7 is a block diagram, which illustrates a configuration of the smoothing unit 15 according to the present embodiment. In Fig. 7, an amount-of-change limit value setting unit 20 sets limit values as to the amount of change between the RGB values, stored in the color correction table, before and after smoothing using the user input values from an input unit 24. A temporary smoothing unit 21 performs smoothing for the RGB values. An amount-of-change computation unit 22 calculates the color difference ΔE between the RGB values before and after the smoothing process performed by the temporary smoothing unit 21. An adjusting unit 23 adjusts the RGB value obtained by

the temporary smoothing unit 21 based upon the color difference ΔE obtained by the amount-of-change computation unit 22, and stores the adjusted RGB value in the color correction table 13.

5 [0040] Fig. 8 shows an example of the display screen for the amount-of-change limit value setting unit 20. The user sets the amount-of-change limit value as the difference ΔE between the RGB values before and after smoothing. For example, in Fig. 8, the color difference ΔE has a value of
10 1.5.

15 [0041] Processing performed by the smoothing unit 15 will now be described according to the present embodiment with reference to a flowchart shown in Fig. 9. First, in Step S901, the amount-of-change limit value setting unit 20 sets the amount-of-change limit value. Next, in Step S902, the temporary smoothing unit 21 performs the smoothing process (which will be referred to as "temporary smoothing" hereafter) for each value stored in the color correction table 13 in a similar way as with in Steps S100 through S105 according to the first embodiment. Subsequently, in Step 20 S903, the amount-of-change computation unit 22 calculates the color difference ΔE between the RGB value subjected to temporary smoothing in Step S902 and the RGB value before temporary smoothing. The color difference ΔE between the 25 RGB values before and after temporary smoothing is

calculated as described below. First, patch images before and after smoothing are formed on the computer system with the color-coordinates of regularly spaced grids formed in the RGB color space. Color patches for the patch images are output from the printer, and color measurement is performed for the output image, whereby the $L^*a^*b^*$ color value corresponding to each color patch is obtained. Subsequently, the $L^*a^*b^*$ color values corresponding to the color correction table 13 before and after smoothing are obtained using interpolation and the results from the aforementioned color measurement. The color difference ΔE is calculated from the two $L^*a^*b^*$ color values. The color difference ΔE between the RGB values before and after smoothing is also calculated with RGB-Lab conversion calculation based upon psychological attribute stipulated by CIECAM97s. In Step S904, the adjusting unit 23 compares the color difference ΔE calculated in Step S903 with the aforementioned amount-of-change limit value. If the aforementioned ΔE is greater than the limit value, the flow proceeds to Step S905, otherwise, the flow proceeds to Step S906. In Step S905, the adjusting unit 23 adjusts the RGB value after temporary smoothing so that the aforementioned color difference ΔE is within the aforementioned amount-of-change limit value.

[0042] Fig. 10 shows the relation between the color P_0 (RGB value) before smoothing, P_{temp} after temporary

smoothing, and P' after adjustment in the RGB color space.

As shown in Fig. 10, the adjusting unit 23 (Fig. 7) performs adjustment so that the line from the color point P0 before smoothing up to the color point Ptemp after temporary

5 smoothing passes through the color point P', obtained after adjustment. Subsequently, in Step S906, the adjusting unit 23 stores the adjusted RGB value in the color correction table 13. In Step S907, it is determined whether the smoothing process has ended for all the values of the color 10 correction table 13. If the smoothing process has not ended, the processing shown in Steps 901 through 906 is repeated.

If the smoothing process has ended for all the values in the color correction table 13, the smoothing processing for the color correction table 13 ends.

15 [0043] Note that an arrangement may be made wherein individual amount-of-change limit values are each set for achromatic color and other colors. Fig. 11 shows an example of the display screen for the amount-of-change limit value setting unit 20 in a case of setting individual amount-of-change limit values for achromatic color and other colors.

20 In Fig. 11, reference numeral 110 denotes an item for setting the amount-of-change limit value for colors other than achromatic color. Reference numeral 111 denotes an item for setting the amount-of-change limit value for achromatic color, wherein the user can set the amount-of-

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change limit value for an arbitrary grid point on the achromatic axis. With regard to other grid points positioned between the grid points where the amount-of-change limit values have been set, an amount-of-change limit 5 value is calculated by interpolation, and the calculated results are displayed as a chart as shown in Fig. 11. As for the interpolation method, linear interpolation, or non-linear interpolation using a spline function or the like may be employed.

10 [0044] Furthermore, while description has been made regarding an arrangement wherein the distance in the Lab space, i.e., the color difference ΔE is employed for the amount-of-change limit value, the amount-of-change limit value may be defined in the shape of the distance in other 15 color spaces such as the RGB space or the like.

[0045] With the above-described method, the user can set an arbitrary limit to the change in the value due to smoothing. Furthermore, with regard to the values on the achromatic axis, in the event that the value deviates from 20 the achromatic axis due to smoothing, the value is temporarily projected onto the achromatic axis, followed by the above-described adjustment processing, whereby the change in value is limited while keeping the value achromatic.

25 Other Embodiments

[0046] The present invention is not restricted to the above-described first and second embodiments; rather, various modifications such as those described below may be made, for example.

5 [0047] In the above-described embodiments, while description has been made regarding an arrangement wherein the smoothing process is performed for the data stored in the color correction table in the RGB color space, an arrangement may be made wherein the smoothing process is
10 performed in other color spaces such as Lab, CMY, or the like.

[0048] Note that the present invention may be applied to a system made up of multiple devices (e.g., host computer, interface device, reader, printer, and the like), or may be
15 applied to an apparatus made up of one device (e.g., photocopier, facsimile, or the like).

[0049] Furthermore, an arrangement may be made wherein a system or a device includes a storage medium storing the program code of software for executing the functions
20 according to the above-described embodiments, and a computer (CPU or MPU) of the system or device reads out the program code stored in the storage medium so as to execute the program code, whereby the processing according to the present invention is performed.

25 [0050] Referring to Fig. 12, a modification of the

present invention as applied to computer 120 will now be described. As shown in Fig. 12, the computer 120 comprises a CPU 121, ROM 122, RAM 123, an input interface 124, and an output interface 125. The input interface is connected to a user input device (not shown). Here, the input unit 24 shown in Fig. 7 may be employed as the user input device. Furthermore, the output interface is connected to an unshown display unit or printer. Here, the display unit may display the display screen shown in Fig. 8 or Fig. 11. With the computer 120, the program for controlling smoothing described in the above-described embodiments with reference to Figs. 5 or 9 is stored in the ROM 122 serving as a storage medium, and the program is executed by the CPU 121.

[0051] In this case, the program code itself read out from the storage medium executes the functions of the above-described embodiments, and accordingly, the storage medium, which stores the program code, is a configuration of the present invention.

[0052] As an example of the storage medium for providing the program code, other than the aforementioned example, a floppy (R) disk, hard disk, optical disk, magneto-optic disk, CD-ROM, CD-R, magnetic tape, non-volatile memory card, or the like, may be employed.

[0053] Furthermore, the present invention is modifiable such that program code is written to memory included in a

function expansion board inserted to the computer or in a function expansion unit connected to the computer, following which a CPU or the like included in the function expansion board or in the function expansion unit executes all or a 5 part of the actual processing according to the instructions of the program code, whereby the functions according to the above-described embodiments are executed.

[0054] As described above, even values on the gray axis can be subjected to smoothing based upon surrounding colors 10 while keeping the values in achromatic color. Thus, artifacts can be reduced on a gradation image containing the color components around the gray axis, and furthermore, noise can be suppressed in images containing gray components, thereby improving image quality.

[0055] While the present invention has been described with reference to what are presently considered to be the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. On the contrary, the invention is intended to cover various 15 modifications and equivalent arrangements included within the spirit and scope of the appended claims. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and 20 equivalent structures and functions.